APPLICATION UNDER UNITED STATES PATENT LAWS

Atty. Dkt.: 2606-0006

Invention: LOW COST TRANSPIRED SOLAR COLLECTOR

Inventor(s): ARCHIBALD, John P.

Davidson Berquist Klima & Jackson, LLP
4501 North Fairfax Drive, Suite 920
Arlington, VA 22203
(703) 248-0333 Phone
(703) 248-9558 Fax

This is a:

- ☐ Provisional Application
- ☒ Regular Utility Application
- ☐ Continuing Application
  ☐ The contents of the parent are incorporated by reference
- ☐ PCT National Phase Application
- ☐ Design Application
- ☐ Reissue Application
- ☐ Plant Application

SPECIFICATION

TITLE OF THE INVENTION

LOW COST TRANSPIRED SOLAR COLLECTOR

TECHNICAL FIELD OF THE INVENTION

This invention relates to an apparatus for collecting radiant solar energy and more particularly to a low cost, modular, adjustable solar energy heater which can be mounted on any surface exposed to the sun and which provides enhanced solar energy collection for surfaces which receive sun at low angles.

BACKGROUND OF THE INVENTION

In the United States, nearly two thirds of the energy used in buildings and facilities is to provide heating for interior spaces, water, and various other residential, commercial, and industrial heating needs. Typically, the heat provided is derived from natural gas, fuel oil, propane, and electricity. These energy sources are sold to customers at commodity rates.

A known but less developed source of energy for heating is solar energy. To be cost competitive with the typical energy sources, solar collectors must deliver heat for the same or lower cost as the other sources. To be competitive in performance, solar collectors also need to deliver a substantial portion of the energy that would otherwise be delivered by traditional energy sources. In the past, large solar collectors have been required to provide a substantial capacity, since they must operate with a relatively small

solar insulation resource of approximately 300 BTU/square foot/per hour during peak solar conditions.

Although much effort has been put into developing solar energy sources in the last 30 years, widespread penetration in the markets has not occurred. In many cases, this is because the collectors themselves have been too complicated, too expensive and the delivered cost of solar energy (including the amortized capital cost) has been higher than traditional gas, oil, and electricity costs. Collectors which cost $20 per square foot sell about 400,000 square feet per year in the United States. Only in the low cost, polymer based, swimming pool heating technologies, which sell for about $2.00 per square foot, have suitable cost and acceptable performance permitted sales of 7-8 million square feet of such solar collectors per year in the United States. A lower cost, higher performing solar collector can significantly improve results and the economics of its use to thereby generate increased sales.

Numerous solar heating system designs have attempted to provide heat for useful purposes. In many cases, the systems have been complex and, as a result, expensive to assemble and install. Some cases have required that the solar collector be tilted up to face the sun during the mid-day hours. The addition of mounting hardware is one of the items raising the cost of these collectors.

Many solar collector systems use flat glazing panels to keep the warm, solar-absorbing surfaces separated from the cold outside temperatures and the detrimental effects of wind.

The most common approach is to create a structural frame around the perimeter of the collector to hold the glazing panel above the absorber. When glass panels are used, the frame must be quite rigid and heavy relative to the active absorber and solar heat transfer fluid. The frame also transmits the pressure from wind loads and the weight of snow loads (often more than 40 pounds per square foot) to the underlying roof or support surface. The rigid frame adds considerable expense to the cost of the collector. It also prevents the collectors from nesting together efficiently to allow a simple, easily made connection from one collector to another to pass the solar heated transfer fluid. Passing the solar heat transfer fluid through multiple collectors is a valuable method of raising the temperature of the heat transfer fluid and increasing the capacity of the system.

Many solar heating systems are capable of collecting and delivering only about 30% of the solar energy that falls on the collector. A few are capable of operating at much higher efficiencies, approaching 80 %. These high efficiency systems can deliver more than twice as much energy per square foot, often for a lower installed cost, resulting in a lower delivered cost of energy.

One method of reaching this high efficiency is to use a transpired solar absorbing surface. Such a surface is generally composed of a dark porous material exposed to sunlight. The surface could be a fabric, screen, perforated metal, metal lath, or fiber batting or pads. United States Patent No. 201,439, Moreau, shows a system of blackened copper wire gauze folded or arranged in peaks and valleys within a glazed collector frame. When exposed to sunlight, the sun heats the various small fibers or elements of the gauze

absorber and, as air passes through the gauze, the air is heated. Moreau uses a glass covered box structure to enclose the gauze, and has the gauze in contact with both the interior surfaces of the glass and the bottom of the box to prevent short circuiting of the air from inlet to outlet. No other specific support of the gauze is identified, although copper wire gauze is stiff enough to be formed into and retain a shape similar to the peaks and valleys shown in Fig. 2 of Moreau.

Other patents using transpired absorbers show different methods of forming absorber. One such method is hanging the absorber vertically and stacking absorber layers on spacers, but separated from the light transmitting cover plate.

US Patent 3,863,261, Schoenfelder, describes a partially transpired collector in which tabs of metal are bent up from a plate to protrude into an air flow path. Both the plate and the tabs collect solar energy and transfer the energy to the air flowing against the plate and through the tabs. Neither the absorber plate nor the tabs touch the light transmitting cover plate.

US Patent 4,217,833, O'Hanlon, shows a wall comprised of a corrugated cover spaced away from a solar energy absorbing flat screen. Air passes once through the screen or screens. US Patents 4,073,282, Schriefer, and 3,875,925, Johnston, show a similar arrangement of light transmitting cover spaced away from the heat absorbing metal lath, with air making one pass through the lath.

These traditional methods of supporting the transpired absorber add considerable expense to the collector. Copper wire gauze is an expensive absorber material currently selling for over $3 per square foot compared to a more modern material, such as polymer fabric, which is lower cost, at about $0.20 per square foot, and which provides similar absorption of solar energy, but does not have the stiffness of the gauze.

Testing in the last few decades has shown that when a fluid, such as air, is passed through such a solar heated fabric absorber, the heat transfer between the air and the small fibers or elements is quite high, compared to air moving over a solid flat absorber plate used in traditional solar collectors. The high heat transfer results in a higher energy delivery compared to traditional solar collectors.

One transpired collector called Solarwall® is built without a glazing cover. On calm days the systems achieves high efficiency. However, in winds of 7 miles per hour, it can loose as much as 25% of its productive capacity when operating at high outlet temperatures. The method of enclosing a transpired absorber between a cover plate and supporting bottom plate will maintain high temperature and high capacity by eliminating these detrimental wind effects.

Another version of a solar collector is shown in US Patent # 4,082,082. The top of the air flow passage is covered with a transparent or translucent cover that allows sunlight to pass through to heat fibrous carbon black-filled high density polyethylene which is packed into a plurality of tubes spread out across the collector. Perforated strips cover

manifolds at each end to control the fibrous material and air is forced through the manifolds and the tubes in which it is heated. The disadvantage of such a system is that the fibrous material on the bottom of the tubular passage receives much less sunlight than the fibers nearest the top of the tube. As a result, the fibrous material at the bottom of the air flow passage is not as hot at the fibers at the top. However, the air flow is constant without regard to the height of the flow in the passage. As a result, the air temperature rise across the collector is a combination of low temperature rise at the bottom and higher temperature rise at the top. For that reason, the system can not achieve as high a temperature rise as a system that uses a thin fabric evenly exposed to the rays of the sun as they first enter the collector.

An unglazed transpired solar collector is disclosed in Christensen et al., United States Patent No. 5,692,491. Here a plenum type air collection chamber is formed and a fan pulls air toward and through the plenum. The front surface of the plenum is covered by an absorber plate in the form of a low thermal-conductance material in the form of a rigid or pliable sheet in either single or multiple layers. The precise material can vary among polyethylene or styrene, metal foil, felt fabric or woven or non-oven fabrics. It was believed that for unglazed transpired collectors that a boundary layer of air builds up on the surface of the absorber between the holes and inhibits heat transfer from the absorber to the suction air. Thus, these regions of the absorber will operate at higher temperatures and have higher heat loses than the regions near the holes. Christensen's approach is to use the solar collector as a radiant heater. Air drawn toward the surface by the fan is heated as it flows towards the front surface and that air is then pulled through the

perforations or openings to form a suction stream. The heat is primarily from the absorber surface with the heat from its passage through the perforations being not a major factor in the overall result. Thus, in Christensen, it is the heating by radiation, not by the passage through the collector that matters. Unglazed collectors, however, are not practical in most environments and in colder weather will exhibit major heat losses to the environment.

Traditional methods of assembling the solar collector system components, either on buildings or at ground level, have also increased the cost of the solar hardware to the point that the cost of the system often exceeds the value of the energy it can deliver. However, by taking advantage of additional features of the solar collector hardware, the collector can increase its value beyond that of just the energy delivered. For example United States Patent No. 5,651,226, Archibald, shows a method of using roofing technology to install a solar heating system that is also the weather tight roof of a building, eliminating the cost of a separate roof beneath a collector. The '266 patent employs concave tiles that are attached directly to the absorber surface and form air flow channels between the tile and the absorber for ducting the solar heated air from the collector, thus eliminating the need for a separate support structure for the glazing over of the absorber. Another hardware technique that is derived from the metal roofing industry is the use of long panels which are allowed to expand and contract due to the daily temperature swings of the materials. The long panels reduce handling costs and therefore improve the economics of the delivered energy from the solar collector.

Materials developed in recent years can reduce the cost and prolong the life of certain components of the collector. Polymer based materials used in the agricultural and printing sector offer long service life, good weather resistance, unique structural and performance properties, and are low in cost. Combinations of polymer materials with similar coefficients of expansion can also reduce the thermal expansion stresses on a collector.

It is the object of this invention to apply several novel and non-obvious materials and assembly techniques to the design of a solar collector. The result is to reduce the cost and increase the capacity relative other solar collectors, thereby improving the economics of the delivered energy compared to other solar energy sources and most traditional energy sources.

SUMMARY OF THE INVENTION

The above described disadvantages of the prior art and the desired objects of a low cost and high efficiency solar energy collector are met by the present invention.

In accordance with the present invention, a solar energy receiving surface is a collector of transpired material, for example in the form of a fabric, interwoven between parallel spiral support coils. The transpired material and coils are arranged between and in contact with each of two glazing plates. Fluid, to be heated, flows through the opening formed between the two plates, through the transpired material and through the spiral support

coils. The upper plate is transparent or translucent and allows sunlight to pass through to the transpired material and spiral coils. The transpired material and spiral coils form the solar energy absorbing surface of the collector and become heated in the presence of sunlight. The transpired material is alternately draped or lightly stretched over, then under, the adjacent spiral coils, forming a series of alternating peaks and valleys in the transpired material. The coils provide the structure to support the transpired material as well as the strength to support and position the upper plate at a set distance above the lower plate

The opening into this collector structure is provided at opposing ends of the collector while the opposing sides extending along the top and bottom of the plates are closed by means of formed channels pulled tightly against the plates. These channels can conform to the cross-sectional shape of the collector and the plates or can be u-shaped and be dimensioned to overlap both the top and bottom plates.

The preferred heat collecting fluid is air that is introduced at one end opening between the plates. As the air flow moves through the opening between the plates, it passes through the transpired material and across the spiral coils. Each peak formed by the transpired material draped over the spiral coil requires the air to pass twice through the transpired material and once across the spiral coil. However, it should be understood that water or some other heat absorbing fluid can be used a well, and the sealing between the two plates would simply be made more fluid tight to prevent leaking of the fluid from the system, and the air handlers replaced by suitable water pumps.

In a preferred embodiment, the transpired material, the spiral coils, the channels, and the plates are each formed from the same polymer material. The transpired material can be, for example, a fluid permeable or porous material that will absorb heat energy yet permit a fluid to pass there through. One example could be a polypropylene fabric, such as a woven or knitted shade cloth commonly used in agricultural shading applications, that will absorb between 60 and 70 percent of the sunlight hitting it at right angles. However, other polymer materials could be employed such as, polyethylene, polyester, or nylon. This transpired material could also be in sheet form that is constructed or formed by needle punching or a sheeting product that is otherwise perforated to permit fluid or air flow there through to easily occur without much resistance. Additionally, other forms of material could be used such as an expanded material, a grid or any open network of interconnecting structures.

The transpired material and spiral coils absorb a portion of the sunlight and become heated. As fluid passes through the transpired material and coils, the heat within the transpired material is transferred to the fluid stream. As noted above, the absorbing fabric material is preferably made from an open weave or knit material that will permit fluid flow through the transpired material with a minimal pressure difference between the upstream and downstream sides of the transpired material. The spiral coils similarly become heated and transfer their heat to the passing fluid with minimal resistance to fluid flow.

The absorbing surface is arranged between two plates with the top plate being transparent or translucent, to freely pass sunlight through to the absorbing surface. In a preferred embodiment, the top plate is formed from an extruded, corrugated polymer. The bottom plate may be any material, sufficient to support the absorbing surface and the top plate, and any snow or wind loads that might be applied to the collector. In a preferred embodiment, the bottom plate is fabricated from the same corrugated polymer material to eliminate thermal expansion and contraction issues associated with different materials. A reflective material may be incorporated below the absorber and above the lower plate or incorporated in the lower plate. The reflective material will reflect any sunlight that passes completely through the absorbing surface back up to the bottom side of the absorbing surface, and in view of the desired openness in the transpired material and the spiral coils this can provide an additional energy gain.

In the preferred embodiment mentioned above, if 70% of the incident sunlight is absorbed by the transpired material then 30% passes through to the reflective material and is reflected back to the bottom of the transpired material. If 70 % of the reflected sunlight is absorbed by the transpired material, a total of 91 % of all sunlight is absorbed by the transpired material. Beyond this simple example, the inclination of the transpired material between the peaks and valleys tends to increase the solar energy absorbed by the transpired material, such that 100% of the sunlight can be absorbed. Different transpired materials are currently produced that absorb different amounts of sunlight and vary in the resistance they offer to fluid flow. The diameter of the spiral coils can be varied to increase the height of the peaks of the absorber above the valleys. Adjusting the height

can vary the angle that the transpired material absorber makes with the incident sunlight. This can increase the amount of sunlight absorbed by the 70% absorbent transpired material described above. The combination of transpired material, spiral coil diameter, and fluid flow resistance can be adjusted for a particular application to optimize the energy performance of the system.

The spiral coils are the main vertical support for the upper plate. The spiral coils are capable of withstanding high vertical loads, especially when they are evenly distributed along the length of the plates of the collector ~~coil~~. For example, a 7/16" outside diameter coil made of 1/16" round PVC, having 5 coils per inch can support over 10 pounds of weight per inch of coil laid longitudinally between two plates. By transferring the support of the upper glazing plate to coils, the heavy perimeter frame that supports the upper plate in traditional collectors is no longer required. Only light weight channels are required around the top and bottom edges of the plates whose function is simply to enclose the fluid flow space, not provide support for the structure. Preferably, the channels are configured with a sealing compound to mate with the top and bottom of the upper and lower plates. Reducing the weight of the frame reduces a significant manufacturing expense in traditional collector production, as well as shipping cost of the collector, and labor costs to install the panels compared to traditional collectors.

Since the transpired material and coils have very little surface area actually in contact with the top glazing plate or bottom plate, there is very little conduction of heat directly from the transpired material or coil to the plates. This minimizes conductive heat loss

compared to traditional collectors which usually provides a clamping contact area around the entire perimeter of the top glazing.

Where corrugated plates are used and arranged in parallel fashion, with one above the other, a preferred arrangement of the spiral coils and transpired material is to lay one coil in each trough with the transpired material passing above one coil and below the next adjacent coil. In this manner, the fluid flow will be generally parallel to the transpired material as it moves in the fluid flow path up and down the peaks and valleys, respectively, but will also pass through the transpired material as the fluid flow passes through each coil. Alternative arrangements of transpired material and coils between the plates can also be made.

The collector can be installed in any orientation, on any surface. It can be installed flat on a flat roof or the ground, vertically on the side of a building, or sloped as the sloped roof of a building or on supporting mounts. However, where corrugated plates are used, the absorber, in the form of transpired material, and top plate have a portion of each repeating corrugation that incorporates a slope between a valley and peak. This sloped portion provides a tilted part of the collector, and specifically the absorber material, which can be oriented to accept the sun's rays even at low elevation angles above the horizon. As a result, the collection system can be mounted horizontally and still accept sunlight from low angles. The tilt angle of the absorber can also be varied and adjusted by varying the size of the spiral supports as this will vary the slope between the points where the absorber material contacts adjacent supports within the collector structure.

The capability to mount the collector horizontally, such as simply laying the collector flat on the ground, eliminates the need for complicated mounting fixtures or structures as well as the need for complicated vertical risers for the insulated ductwork that extracts the heated fluid. Eliminating the need for these materials and the labor expense to install them further lowers the cost of the collector.

Fasteners that extend through the bottom plate into a support structure are one means of affixing the collector to a support structure. Fasteners can also be used to further affix the top plate to the bottom plate. This further secures the top plate to the bottom plate beyond the restraining forces from the end closure channels.

Another advantage of the use of corrugated plates is that additional weather proofing can be gained below the collector by varying the fastener placements. Where fasteners pass through the top plate, to attach to the bottom plate, of the corrugated panel, it is best to attach the bottom plate to the support structure in different corrugations than used for the top to bottom plate fasteners. This ensures that any water leakage through the top plate will drain to the end of a corrugation and not into the hole formed by the bottom plate to support structure fasteners.

Another fastening approach is to use clips similar to those used for metal standing seam roofing. These clips are placed at the edges of the top plate and allow sliding due to thermal expansion. Using this approach, the top plates can be made of considerable

length, such as could be produced from a polymer extrusion process. Despite the long length and daily temperature swings, there would be no problem with thermal expansion, since the plate edges would slide within the clip but remain attached to the supporting surface. This allows very large collectors to be assembled with minimal handling of separate components, further reducing labor costs. Similar clips can be attached between the supporting surface and the bottom plate or other arrangements of the clips can be provided to secure the top and bottom plates to the supporting surface.

Where the large areas of collector are required, it may be necessary to combine individual collectors. To do this, the fluid inlet opening from one collector could be inserted into the fluid outlet opening of an adjacent collector. Where corrugated plates are used, the inserted opening should end with a peak corrugation that fits into another peak corrugation. In this manner, any rain that falls will run into the next valley of the inserted plate and drain off the bottom of the plate before entering the fluid flow space. When collectors are combined transversely, as mentioned above, the added number of passes of fluid through the transpired material and spiral coils will further raise the outlet temperature compared to fluid passing though a single collector. Similarly, collectors can be combined vertically by inserting the top of the lower collector with closure channel removed, into the bottom of the upper collector.

Where the fluid is air, air movement through the collector would typically be accomplished by one or more fans sized for the application. However, use of convection currents of vertically sloped panels is also envisioned.

Gasses other than air could also be heated provided they are compatible with the construction materials. Liquids could also be heated using the same general configuration or combinations of liquids and gasses could be heated simultaneously using the same approach.

The bottom plate may be the existing roof of a building or some other existing structure. Preferably, the bottom plate would be a stable material with a high degree of reflectivity, such as a light colored metal or membrane roof of a building.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

For a fuller understanding of the nature and desired objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings wherein like reference characters denote corresponding parts throughout the several views and wherein:

FIG. 1 is a cross sectional view through the collector showing spiral coils, a transpired material between two corrugated plates and an end closure plate;

FIG. 1A is a cross sectional view showing an alternative arrangement for a corrugated top plate and a flat bottom plate;

FIG. 1B is a cross sectional view showing a further alternative arrangement using coils of the same size between flat top and bottom plates;

FIG. 2 is an isometric view of a collector showing a series of spiral coils and a transpired material arranged between two corrugated plates and an end closure plate;

FIG. 3 is an isomeric drawing showing two corrugated plates between two end closure channels;

FIG.4 is a cross sectional view showing two collectors joined together with the fluid inlet of one collector inserted into the fluid outlet of the other collector;

FIG. 4A is an enlarged cross sectional view of a portion of the interconnected panels from FIG. 4; and

FIG. 5 is a cross sectional view of the collector showing various fastener locations and restraining clip.

FIG. 5A is a cross sectional view of the collector showing various restraining clips.

DETAILED DESCRIPTION OF THE INVENTION

Referring now more particularly to FIG. 1, a solar collector incorporates a top glazing plate 1, a bottom glazing plate 2, a solar absorber formed from a transpired material 3 and several spiral coils 4 to constrain the transpired material and provide the structural support for and the spacing between plates 1 and 2. An end closure channel 5 is also shown which closes the opening between plates 1 and 2 along one edge thereof with fluid

flow through the collector being generally from right to left as indicated by the arrow. The top glazing plate 1 and bottom plate 2, as shown, are corrugated plates with identical corrugation patterns arranged one above the other. However, flat plates or plates with curved corrugations could also be used. In addition, combinations of various plate shapes can also be used. For example, in FIG. 1A, the top plate 10 is a corrugated structure while bottom plate 12 is flat. As is shown, two different size coils are used, one 14 having a large diameter, while the other 16 has a relatively smaller diameter. The diameters will be chosen to reflect the dimensions of the corrugations appearing in the top plate. In addition, this structure could be turned over making plate 12 the top plate and the corrugated plate 10 the bottom plate. As was the case in FIG. 1, transpired material 18 will be placed so that it passes beneath one coil, such as the right most small coil 16, and then over the next adjacent large coil 14. As fluid flows through the collector and between plates 10 and 12, the fluid will pass through the right most small coil 16, through transpired material 18, through coil 14, through the transpired material again and so on throughout the remainder of the collector.

It should also be understood that the size of the spiral supports will influence the angle the absorber in the form of the transpired material will have in the collector and to the sun angle. As the coil size increases or decreases the effective tilt angle of the absorber material will change and this allows a great deal of flexibility to maximize the collection effect of the absorber material.

As shown in FIG. 1B, the collector could also be formed from two flat plates 20 and 22 where coils 24 have the same relative diameter to appropriately space plates 20 and 22 apart. As with other embodiments, transpired material 26 will be draped over coils 26 as shown so that it passes in a zigzag fashion from the bottom of one coil to the top of the next adjacent coil.

The coils 4, 14, 16 and 24 can be formed from a plastic or thermoplastic material, metal or other materials. For example, the spiral coils could be as supplied by DELRAN All Binders and Indexes, Inc. having a size of 13mm with a spacing of 5 spirals per inch along the length of the coil and about 36 inches long. The larger size could be 28 mm with a 4 per inch spacing and a length of about 12 inches long. In the case of the 36 inch coils, they are pulled in a uniform manner to a length of about 8 feet prior to use in an 8 foot collector. The 12 inch coils are uniformly pulled to a length of about 32 inches and then laid end to end to make a length of about 8 feet for use in a collector.

In place of coils 4, 14, 16 and 24, the supporting structure could have other forms so long as it remains porous, perforated, honeycombed, perforated, permeable or is otherwise open to fluid flow. Several other forms of the support are shown in FIGs. 1C – 1F. I FIG. 1C a perforated tube 30 having holes 32 spaced out along the length thereof. FIG. 1D shows a triangular shaped support 34 with openings 36 again being provided at spaced apart locations along the support. This is not shown with an interconnecting wall or connection between the two downwardly extending legs, but such an interconnection could be provided. FIG. 1E shows a u-shaped support 38 that is provided with holes 40

that are at spaced apart locations along the support 38. FIG. 1F shows another form of a u-shaped support 42 where the openness is provided by a plurality of spaced apart ribs 44 that are spaced apart and depend from a central spine 46. Each of these alternative supports can be molded, formed from an extruded member or formed from pieces separately manufactured. The material is preferably a plastic material, but other materials could be used including aluminum, copper, other metals, or combinations of materials including combinations of different plastics or other man-made materials, including reinforced materials.

With reference back to FIG. 1, the transpired material 3 is alternately interwoven above and below the spiral coils 4 which are arrayed within each of the separate corrugations. The transpired material is alternately pinched between the top glazing plate 1 and the top of the spiral coils 4 and between the bottom plate 2 and the bottom of the spiral coils 4. The weight of the top glazing plate 1 is supported by the rigidity of the spiral coils 4. The spiral coils 4 are supported by the bottom plate. The bottom plate is supported above any supporting structure. The spiral coils can be sized to resist loads from the top plate, such as snow loads and wind loads.

Fluid flows between the top plate 1 and bottom plate 2. The fluid flows through the open spaces in the spiral coils 4 and through the open weave of the transpired material 3. As sunlight falls on the transpired material and spiral coils, they become heated. As fluid moves through the heated transpired material 3 and coils 4 the fluid, being relatively cooler, absorbs the heat from the transpired material 3 and the coils 4 and becomes heated

thereby. Fluid will flow through the transpired material 3 several times along the collector and through several spiral coils, as it moves across the full width of the collector. During each instance where the fluid passes through the transpired material and the coils the temperature of the fluid will incrementally increase to the limits of the collector's heating capacity for a given fluid flow and the out-door conditions. Collectors may be sized with one peak or valley or any number of peaks and valleys to deliver an appropriate temperature rise in the fluid for a specific heating application.

The closure channel 5 is arranged to extend along the whole of the collector’s top and bottom edges or sides and will compress against the top and bottom plates in order to prevent fluid flow from entering into or leaving from the fluid flow path that begins and ends at the respective opposing ends. Channel 5 is not designed as a weight bearing structure to support the top and bottom plates, but functions rather as a ~~an~~ fluid sealing device. As a result, it can be quite light weight compared to the rigid frames often associated with traditional solar collectors.

Referring to Figure 2, the components of the collector are readily visible in the isometric view. More particularly, the end closure channel, 5 is shown in channel form. It should be understood, however, that the channel could mirror the cross sectional shape of the top and bottom plates, whether those plates are in the form of flat sheets, corrugated sheets, curved sheets or some combination of such shaped sheets. The spiral coils are shown in spiral form, which was not evident in the section view of Figure 1, and this is exemplary of the stretched coils discussed above. The transpired material absorber 3 is not shown as

extending continuously over the left most spiral coil 4 in order to provide clarity within the illustration. However, the transpired material is intended to continue over the left most coil 4 to the end of the collector structure. Similarly, the transpired material 3 is intended to continue under the right most coil 4, but it is not shown for clarity purposes.

Referring to Figure 3, a more complete isometric view, and includes both side enclosing channels 5, the top and bottom plates, 1 and 2 respectively, and further shows the open opposing ends through which fluid flow occurs

Figures 4 and 4A show two collectors A and B that are connected together to thereby increase the capacity of the collector system. Collector A, on the right side, has its fluid flow outlet A' inserted into the fluid flow inlet B' of collector B positioned on the left side. The details of this A'/B' joint are shown in an enlarged view of FIG. 4A where the collector A outlet is defined by top plate sections 30, 32 and 34 and bottom plate sections 36, 38 and 40. In a similar fashion, collector B's inlet B' is comprised of top plate sections 50, 52 and 54 and bottom plate sections 56, 58 and 60. In particular, section 34 fits or slides beneath section 54 and section 40 fits or slides on top of section 60. This interfitting of these sections of the top and bottom plate corrugations directs any precipitation that might fall on the collector's top plate to run down into the adjacent valleys of the corrugations, without entering the fluid flow path within the collector.

Figure 5 shows alternative methods of applying and using various forms of fasteners to hold the collector in place on a support 74. For example, two corrugated plates, a top

plate 70 and a bottom plate 72, are shown on support 74 with spiral supports 76 and a transpired material 78 being held in place between the two plates 70/72 as in the prior examples discussed above.

An end style restraining clip, 100, is shown at the right hand side of FIG. 5 as engaging both the top plate 70 and the bottom plate 72 and for restraining the engaged portions and for attaching such plates to the supporting structure 74 with fastener 102. Another end style restraining clip 104 is shown as engaging and restraining both the top and bottom plates, 70 and 72, respectively, simultaneously at the opposite end of the structure. A third clip 106 is shown engaging and restraining the top plate 70 and bottom plate 72 where adjacent plates overlap.

Restraining clips 100 and 104, used at the ends of the collector, are formed in the same manner and are mirror images of the other. An enlarged view of clip 104 is shown in FIG. 5A, but it should be understood that clip 100 has the same configuration and is simply reversed I its direction of use. Clip 104, as in FIG. 5A has upper and lower clip sections, with the upper section comprised of an upper flange 108 and a lower flange 110, while the lower section is comprised of an upper flange 112 and a lower flange 114. Each flange extends from a vertical member 116 and a foot piece is provided at 118. Each upper flange is spaced from the lower flange so that the edge of the panel can fit therein and be vertically restrained yet move horizontally. It should also be understood that clips 100 and 104 are identical in cross-section but reversed in their direction of use.

Yet another style restraining clip is used along an intermediate section of the collector where top and bottom plates overlap. One of these is shown in FIG. 5 at 106 and an enlarged view is set forth in FIG. 5 B. In FIG. 5B clip 106 includes a series of alternating and oppositely facing cavities formed by a series of stacked flanges that are interconnected. For example, a top flange 120 overlies a flange 122 forming a cavity 130. Flange 122 is connected to an intervening structure 124 that provides a connection to another flange 126 that connects to the bottommost flange 128. A cavity 132 is formed beneath flange 122 and a cavity 134 is defined between the bottom of flange 126 and the top of flange 128. A final cavity or space 136 is defined below flange 128. In FIG. 5B, cavities 130 and 136 open to the left while cavities 132 and 134 open toward the right. This series of cavities or spaces 130 - 136 permits the ends or edges of the overlapping panels 70 and 72 , shown in dotted lines in FIG. 5B, to fit into the cavities in which the panels are thereby restrained vertically.

Each of clips 100, 104 and 106 are preferably cut from an elongated extrusion, as noted above, but could be formed from sheet metal sections fastened together.

Numerous additional clip arrangements or profiles can be provided for different plate configurations and areas where plates terminate or overlap depending upon such factors as the shape and size of the edge, edge dimensions, the angles of the edge and size and location of the supports between the plates to be restrained.

Figure 5 does not show the transpired material absorber 78 as continuing across the clip 106 at the joint between adjacent plates. In an alternate arrangement, however, the transpired material absorber 78 may be arranged around the clips 106 by cutting the transpired material in way of the clip, or folding short lengths of transpired material around the clip and over the spiral 76 adjacent clip 106. In yet another alternative arrangement, a continuous length of the transpired material absorber, that is wide enough to span the assembled width of the plates, would be installed transversely across the plates. The absorber material would be cut in strips to a length that is roughly equal to the longitudinal clip spacing. Similar cut strips of absorber material would be installed between successive clips up and down the length of the plates.

FIG. 5C shows several additional modifications that can be used with the present invention. A top plate to bottom plate fastener 80 provides a positive attachment mechanism between the two plates 70 and 72. Fastener 80 positively locates and holds the left most coil 76 in place and passes through the transpired material 78 to secure it relative to the plates 70 and 72. Fastener 80 is shown in a preferred location on an elevated part of the corrugations. In this location, any water leakage that may occur through the top plate 70 would likely run down into an adjacent corrugation valley in which there is no fastener so that the water would flow to the end of that particular corrugation in the collector without penetrating to the support structure below. Note that in the next adjacent corrugation there is a fastener 82 which holds the bottom plate 72 to support 74 at a point spaced from the previously noted intervening corrugation valley. Using this location for fastener 82 assures that the upper plate 70 is solid will resist any

infiltration of precipitation above fastener 82. At the right end, a retainer 100, as described above, is used to hold the collector to support 74 such as by a nail 102.

While a fan was referenced above, a fan 95 can be mounted to the collector of the present invention in a variety of ways, one being to use a manifold 93, as shown at the left side of FIG. 5C, secured to the top and bottom plates, 70 and 72, respectively, and enclosing the fluid space defined thereby. Suitable ducting 94 will extend from manifold 93 to the fan 95 and outlet ducting 96 can be used to convey the heated fluid from the fan to any device or area requiring heat (not shown).

For collectors of considerable length, use of the above described restraining clips is a preferred method of attachment to the alternative of screws or nails. Such restraining clips can be produced in a variety of shapes or configurations, as shown, to conform or fit around various plate shapes and to thereby restrain variously shaped collector plates. The restraining clips fit around the plates to hold them vertically to the support yet allow for horizontal movement associated with thermal expansion and contraction along the length of the plates and various clip types are widely used in the roofing industry. In a preferred arrangement, the clips are placed at approximately 18 inch intervals along the length of the plates. Clips are approximately 3 inches long and are fabricated from bending sheet metal of adequate thickness to resist wind forces on the plates. Alternatively, the restraining clips can be cut from elongated molded extrusions and be formed from suitable plastic materials such as polymers, polycarbonate, polyethylene or other thermoplastics or thermoset resins.

FIG. 6 shows an alternative embodiment of the present invention. The collector 200 includes a sheet of the transpired material 202 that is positioned between top and bottom plates, 204 and 206, respectively, of the collector 200. Unlike the previous embodiments, however, the sheet of transpired material 202 is attached so that it is taut between the tops of the corrugations 208 of the bottom plate 206 and the bottom of the corrugations in the top plate 204. As a consequence, the top plate 204 rests on the taut transpired material 202 and is held up thereby. Clips 210 can be used at spaced intervals along the side of collector to hold the top and bottom plates 204 and 206 to an underlying support 212.

The transpired material 202 can be connected to either the top plate 204 or bottom plate 206. Further, the transpired material 202 can be attached only at the ends of one of those plates or to one or more of the corrugations in which it is in contact. Attachment can be by way of adhesive, hot melt glues, spot welding, by way of a mechanical device such as screws or clips, any other approach that will securely bond the transpired material in place and maintain the desired degree of tautness. The transpired material 202 can be stretched or attached so that some degree of a conforming drape can exist between the material and the plate structure to which it is attached. In addition, the top plate does not need to have the identical corrugated shape as the bottom plate as long as there can be fluid flow through the assembled collector structure and through the transpired material.

With reference to FIG. 6, fluid flow can be from right to left, as indicated by the arrow, with the fluid entering from the right side and then flowing through the first segment of

transpired material 202 adjacent the right side. Fluid flow then moves downwardly into the first corrugation of the bottom plate 206 and then that corrugation will redirect flow upwardly at the next segment of the transpired material. This zig zag flow will then continue along the length of collector 200.

It is understood that the description illustrates several preferred embodiments but that there are many other variations known to those skilled in the arts that are also covered by the invention.